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CHESTNUT BLIGHT IN THE SOUTHERN APPALACHIANS

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The parasitic fungus which causes the disease of chestnut known as the blight or bark disease was brought into the United States from Asia on small nursery trees before this country had enacted plant-quarantine laws. As is often the case with introduced plant and insect pests, the chestnut-blight organism proved to be a more virulent parasite in the home of its adoption than in its native habitat. Millions of acres of chestnut, dead and dying as a result of this introduction, bear mute testimony to the need of proper plant-quarantine laws. The chestnut blight was first observed and recognized as a new disease in this country at New York City in 1904, though it must have been present for some time previous to that date. To-day the chestnut north of the Potomac River and east of the Allegheny Mountains has been laid waste by the blight fungus. The remaining American chestnut stands of the southern Appalachian Mountains face certain destruction.

This circular gives the known distribution of the disease, as determined by a partial survey made during the summer and fall of 1924 and 1925 by several members of the Office of Forest Pathology. State and national foresters, pathologists, county agents, and many private individuals have assisted in this survey work, and the con-

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tinuation of this cooperation is necessary in order to secure needed information with the limited funds available for inspection. Forecasts on the future spread of the blight also are given.

SYMPTOMS OF THE DISEASE

In stands recently attacked the first evidences of the disease are generally to be found on the smaller branches and at the bases of young sprouts from stumps. When such branches and sprouts are killed by the blight during the growing season the dead leaves and burs adhere tenaciously, forming characteristic "flags," which are very helpful in locating infections from a distance. These show up in summer in striking contrast with the healthy green leaves and in winter with the defoliated remaining portions of the trees. Close examination will determine whether these flags are due to the disease or to mechanical injuries. If the symptoms are caused by the blight, prominent lesions on the branch, trunk, or even exposed roots indicate the growth of the parasite within the bark. These areas of diseased bark vary in size, color, elevation, and the fruiting structures produced.

The cankers are generally elliptical in outline at first. Because the growth of the fungus is slightly more rapid up and down the stem, the longer dimension of the lesion lies in that direction. When the two edges of the lesion meet around the stem (Pl. I) the resulting ring of diseased tissue cuts off the flow of sap. The foliage above such a girdle wilts, turns yellow, and dies. Usually it does not fall, but remains persistent for a considerable period. There is usually a development of sprouts or suckers below the girdle (Pl. II).

The cankered areas may be either sunken below or swollen above the surrounding bark, or they may be combinations of the two. On smooth bark the lesions are sharply demarked, sometimes even appearing as though outlined with black pencil lines. The margin may be raised or slightly water-soaked when the fungus is advancing rapidly. It is usually regular, but in some cases it is so irregular as to resemble amœboid flow, as shown to a slight extent in Plate I. At times the reddish orange color of young cankers stands out in striking contrast with the green bark, but both normal and diseased barks darken with age, and the coloration of the canker becomes less conspicuous when it assumes its usual red-brown to sepia tones. With increasing age cankers generally become rough, split, and cracked, with peeling bark (Pls. III and IV). The sunken cankers, which are generally smooth barked at the center, often develop roughened raised margins. Mature portions of cankers are dotted with fruiting structures, which most commonly resemble orange or red-brown pinheads. These fruiting bodies are more conspicuous on smooth lesions, but are also evident in the cracks of rough cankers.

Many cankers show the points at which the fungus organism entered the bark. Wormholes, cicada stings, and mechanical injuries are favorite points of attack. Diseased twigs frequently carry infection into larger parts. Sprouts are commonly infected where spores and moisture collect at their bases.

In chestnut stands where blight has been established for a number of years the effect of the disease is so striking as to be evident to the most casual observer (Pls. V, VI, and VII). Dying limbs with attached browned leaves and burs seem scorched by fire. Branches and trunks stand dead. Sprouts grow from the bases of blight-killed trees. In turn, they too become infected. Insects and sap rots attacking the dead trees cause the bark to peel and add to the somberness of the picture.

When the bark is peeled back from a canker the infected part is typically found to contain numerous flattened layers of branching mycelium known as fans (Pl. VIII). Their presence is one of the best diagnostic symptoms of chestnut blight. Specimens should be examined for them when any doubt exists as to whether or not a diseased condition is due to blight.

This test is especially valuable in distinguishing between injury caused by blight and that due to root rot, for the latter is the disease with which chestnut blight is most often confused. Root rot is general in southern chestnut at the lower elevations. Unlike the recently introduced blight, it is of long standing. Its prevalence accounts in part for the recession of chestnut, which is known to have been taking place during the past 75 years. In advanced stages root rot occasionally kills the entire tree at once, but more often produces the bare top branches known as a staghead. Early stages of root rot are easily confused with the blight, especially during drought. Viewed from a distance the symptoms of this stage of the disease differ from those produced by blight only in being less sharply confined to particular limbs and in the foliage being more yellow in appearance. Closer inspection should show no cankers with their characteristic fans if the injury is due to root rot. Chestnut blight does not attack roots which are covered by soil.

CAUSAL ORGANISM

The fungus *Endothia parasitica* (Murr.) A. and A. growing within the bark and outermost wood layers of the American chestnut (*Castanea dentata* Borkh.) causes the disease known as chestnut blight. The vegetative part of the fungus, which is made up of very numerous closely appressed threadlike strands, is called the "mycelium." It grows through the bark, pushing out and extending much as the roots of higher plants force themselves into soil. As the fungus penetrates, it brings about the death of the invaded bark. The mycelium within this dead area is buff colored, but where it extends into the living bark at the margin of the lesion it is often white. The term "fans" has been applied as descriptive of these thin spreading plates of fungous growth.

When well established the fungus fruits. The reproductive bodies formed, corresponding to the seeds of higher plants, are known as spores. Two types of spores are produced by the chestnut-blight fungus. Both kinds arise from pustules, which in dry weather resemble orange or red-brown pinheads dotted over the surface of the cankers (Pl. IX, A).

During damp weather certain pustules produce tiny yellow, coiling hairlike tendrils called "spore horns" (Pl. X), which are com-

posed of myriads of spores about the size of bacteria. These spores are borne within the pustule in such numbers that when moist they are forced out in a slender serpentine mass, much as paste is squeezed from a tube. Spores of this type are sticky. They adhere to birds and insects coming in contact with them and thus may be carried long distances. Rain dissolves the spore horns and so spreads infection on trees already diseased.

Pustules producing the second type of spore differ from those producing the first in that during wet weather they are dotted with very small openings rather than surmounted by spore horns. The openings, which are often at the end of small protuberances (Pl. IX, B), are the mouths of flask-shaped structures. Within the flasks the spores are borne, definitely arranged in groups of eight 2-celled spores. Each group is inclosed in a thin transparent club-shaped sac. Under suitable conditions the sacs escape through the neck of the flask. When free the sacs burst in miniature explosions, throwing the spores into the air. Thus freed the spores are carried by air currents, often to great distances.

The enormous numbers in which both types of blight spores are produced, together with the fact that they are adapted for different methods of dissemination, give insight into one aspect of the difficulty of halting such a foreign invader once it became widely established and began its march.

SPREAD OF THE BLIGHT

The original infection spread rapidly from its center at New York City, and later from other centers. It soon spread over New England, but made its most rapid advance from New York City in a southwesterly direction along the southeastern slopes of the Blue Ridge and Allegheny Mountains.

Even in a given direction advance is not uniform. Not only does the blight fungus spread from infected trees to healthy ones near by but it is often carried for many miles—sometimes hundreds of miles—on shipments of chestnut lumber or nursery trees, by migrating birds, wind-blown insects, or the air itself. Under favorable conditions such spores may produce new centers of spread known as spot infections or advance infections. The rapid progress of the blight over the chestnut area is largely due to the starting of these advance spot infections many miles ahead of the main infection area. These advance spots rapidly enlarge and run together, forming a continuous infected area. The method of the delay and control work in Pennsylvania and other States was to locate and eradicate these advance infections. For instance, the eradication of the large Georgia-Tennessee spot infection when it was still small would have resulted in delaying the time of the death of the chestnut growth of that part of the southern Appalachians for many years, as the main infection area is still hundreds of miles north of this large infected area. The work in Pennsylvania resulted in marked delay in the spread of the disease westward across that State. Valleys or other areas with limited chestnut growth also delay the spread. Conversely, certain tracts of timber located within the infected area may for a time be disease escaping and be little infected by the fungus.

Their condition and location materially affect the rapidity with which trees become infected. Those along the edges of woods and roads and isolated trees are not only more exposed to spores of the fungus but also have more mechanical injuries. Various mechanical injuries and the work of insects afford places of entry for the parasite.

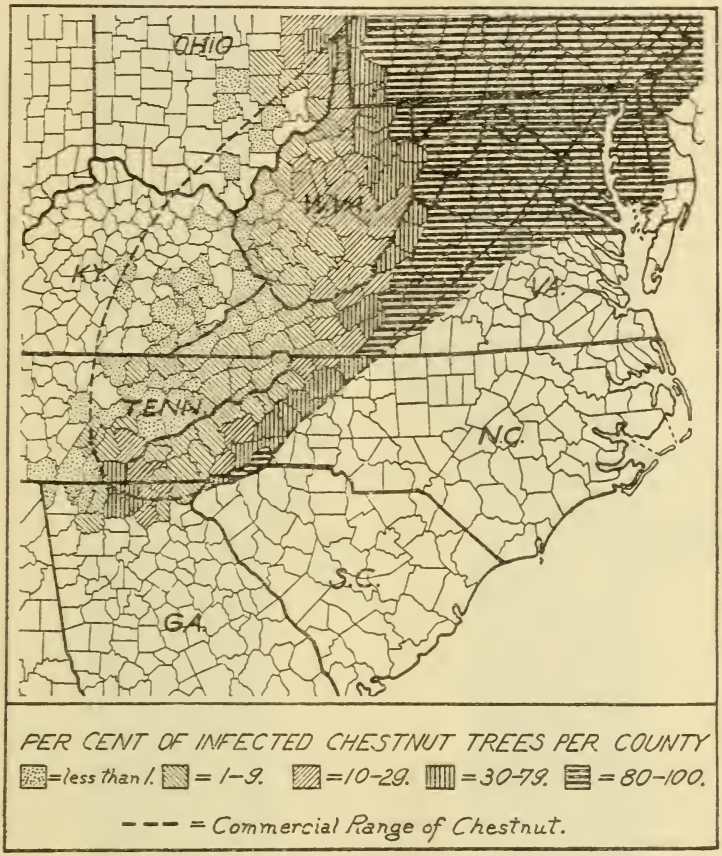


FIG. 1.—Map showing the known distribution of chestnut blight in the southern Appalachians in March, 1926

PRESENT DISTRIBUTION

The distribution of the chestnut blight in the southern Appalachians is shown on a map (fig. 1), which presents the data from the incomplete survey of 1924 and 1925, supplemented by the reports of numerous cooperators. Table 1 briefly summarizes the survey of 1925. The degrees of infection which the table and map show are based upon the average percentage of chestnut trees infected within a given county (fig. 1). The actual degree of infection within a county varies greatly. For example, a county noted on the map as having an average of 50 per cent blight may contain tracts where the actual infection is less than 5 per cent and other tracts where the extent of the infection may be 95 per cent.

TABLE 1.—*Summary of the 1925 survey of 200 of the more important chestnut counties in the southern Appalachians*

Extent of blight (percentage of trees infected)	Number of counties inspected							
	Georgia	Kentucky	North Carolina	South Carolina	Tennessee	Virginia	West Virginia	Total
No infection	3	8	0	0	1	0	0	12
Less than 1 per cent	3	14	0	0	14	5	4	40
1 to 9 per cent	4	0	11	1	15	6	14	51
10 to 29 per cent	3	0	5	0	1	4	20	33
30 to 79 per cent	2	0	7	2	1	6	8	26
80 to 100 per cent	0	0	1	1	0	27	9	38
Total	15	22	24	4	32	48	55	200

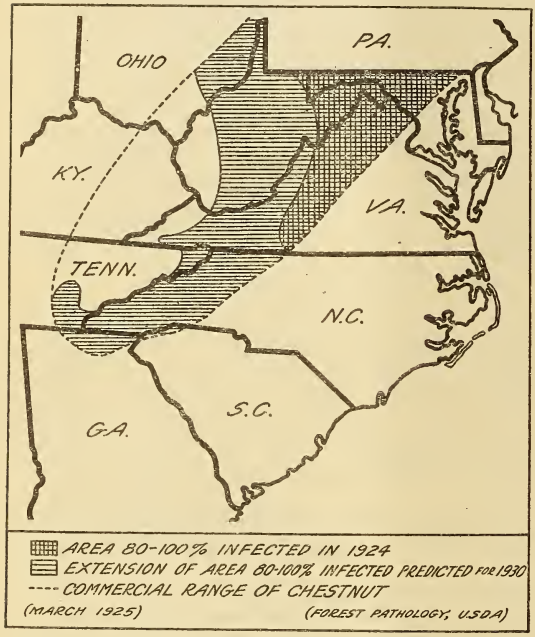
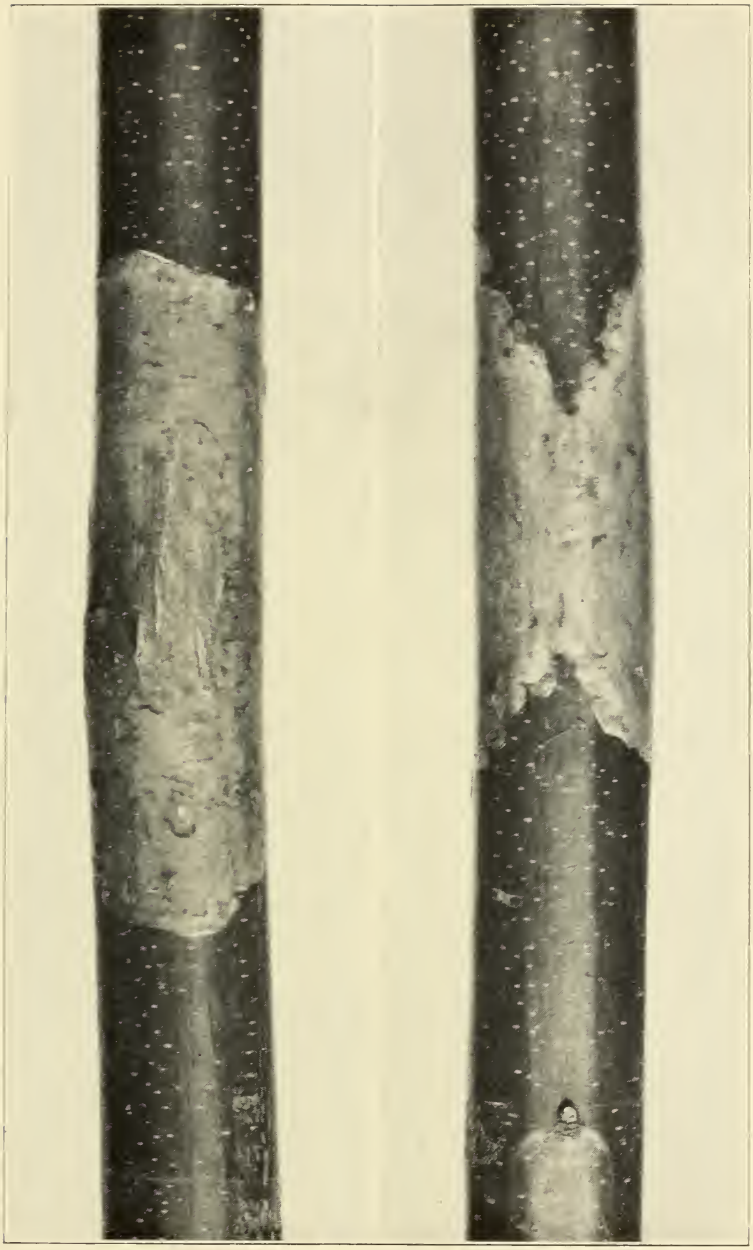


FIG. 2.—Map forecasting 80 per cent chestnut-blight infection in the southern Appalachians

There are probably many inaccuracies in these estimates. Some of the counties within the commercial range of chestnut (fig. 1) have not yet been inspected. In most of those which were entered the inspection consisted of a single automobile trip across the county, which afforded a view of but a fractional part of the chestnut stand for the entire county. The necessary adherence to a county basis did not increase the accuracy of mapping the distribution of the blight. The distribution presented on the map is based merely upon the best averages available in March, 1926. The need for each individual owner of woodland to examine his chestnut stands and determine roughly the present status of blight in them can not be emphasized too strongly.

FUTURE SPREAD OF THE BLIGHT

In the early stages of infection the presence of blight in chestnut stands is not evident to the casual observer. At first, only a few of the smaller branches and sprouts are killed. A 1 per cent infection, for example, since it refers to the presence of one or more infections on one in every hundred chestnut trees, actually represents a diseased condition of a very small fraction of the total branch spread.



A YOUNG CHESTNUT-BLIGHT CANKER

The girdling of a sprout by the meeting of the two edges of the lesion has just been completed. (Natural size)

A CHESTNUT-BLIGHT CANKER WITH SWOLLEN EDGES AND WITH THE DEAD BARK PEELED FROM THE WOOD IN THE CENTER

A CHESTNUT TREE ALMOST KILLED BY BLIGHT

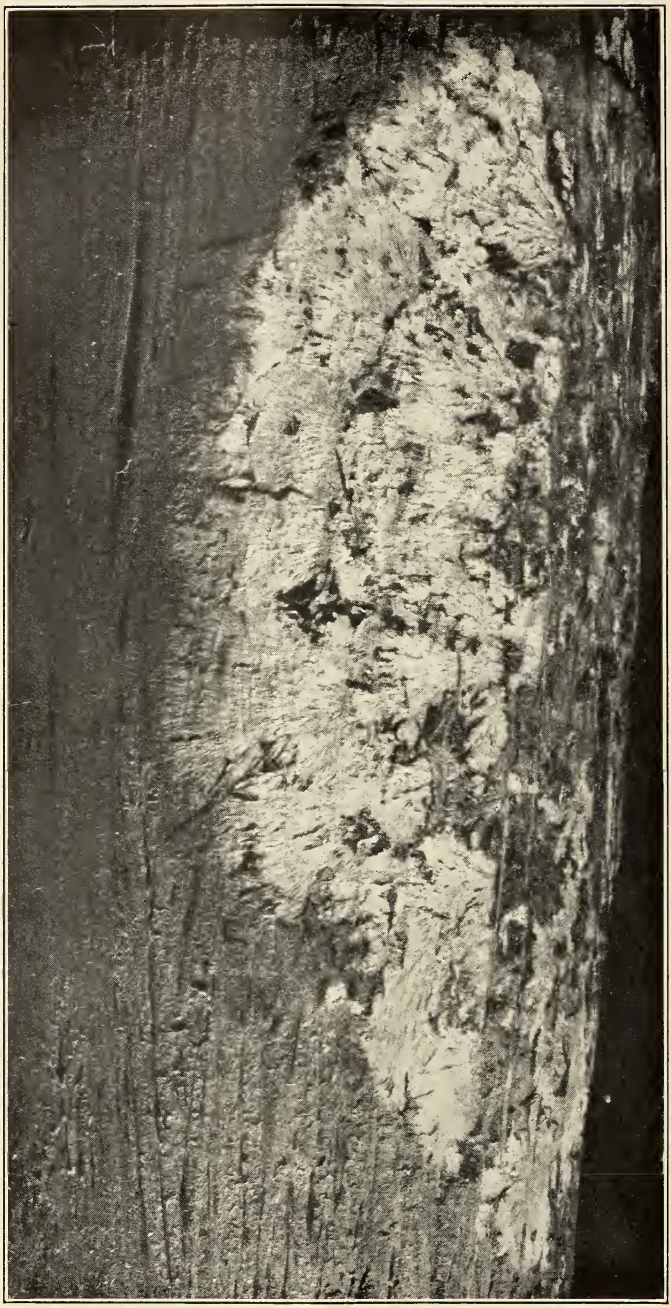
The abundant development of sprouts along the trunk is often found

CONDITION OF CHESTNUT GROWTH NINE YEARS AFTER IT REACHED THE STAGE OF 80 PER CENT INFECTION

The uninjured trees are species other than chestnut

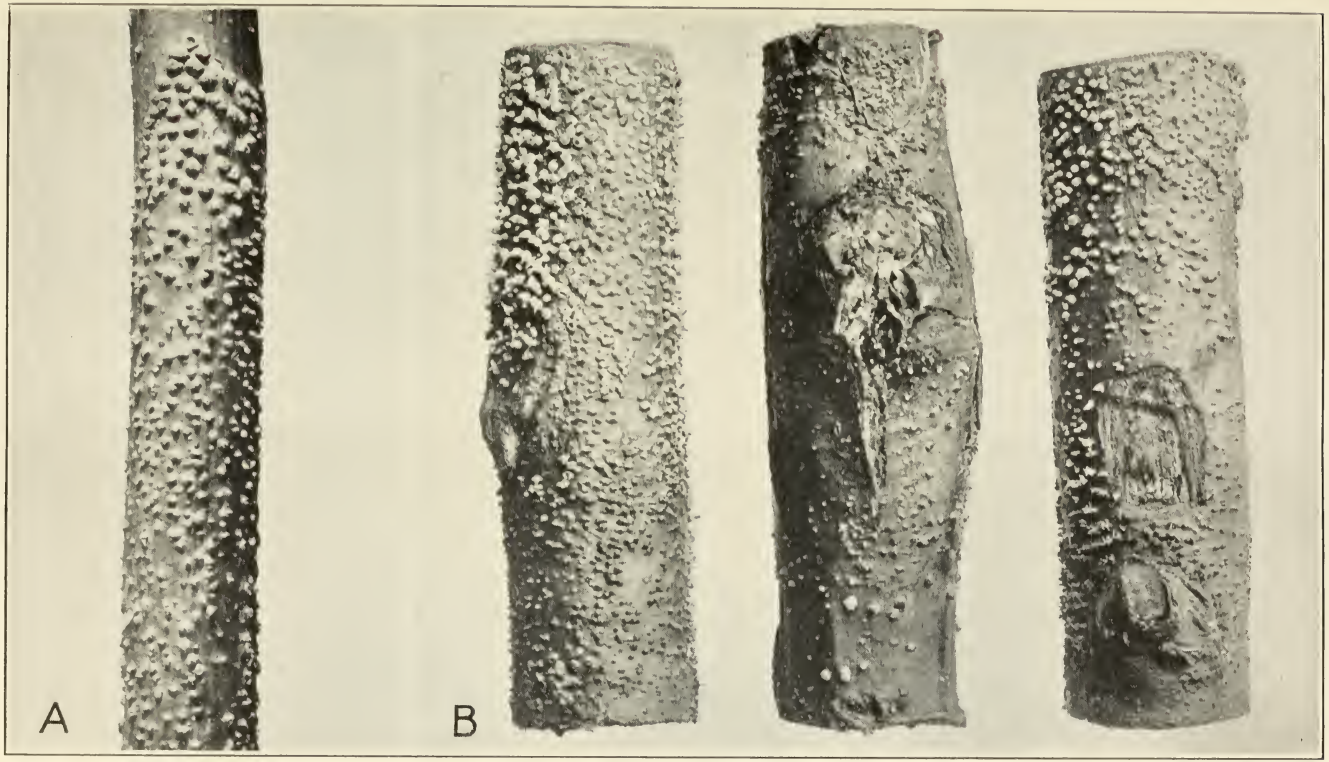
CHESTNUTS WHICH HAVE BEEN DEAD FROM FOUR TO SIX YEARS

Most of the bark has fallen, the sapwood is decayed, and checks in the wood are numerous



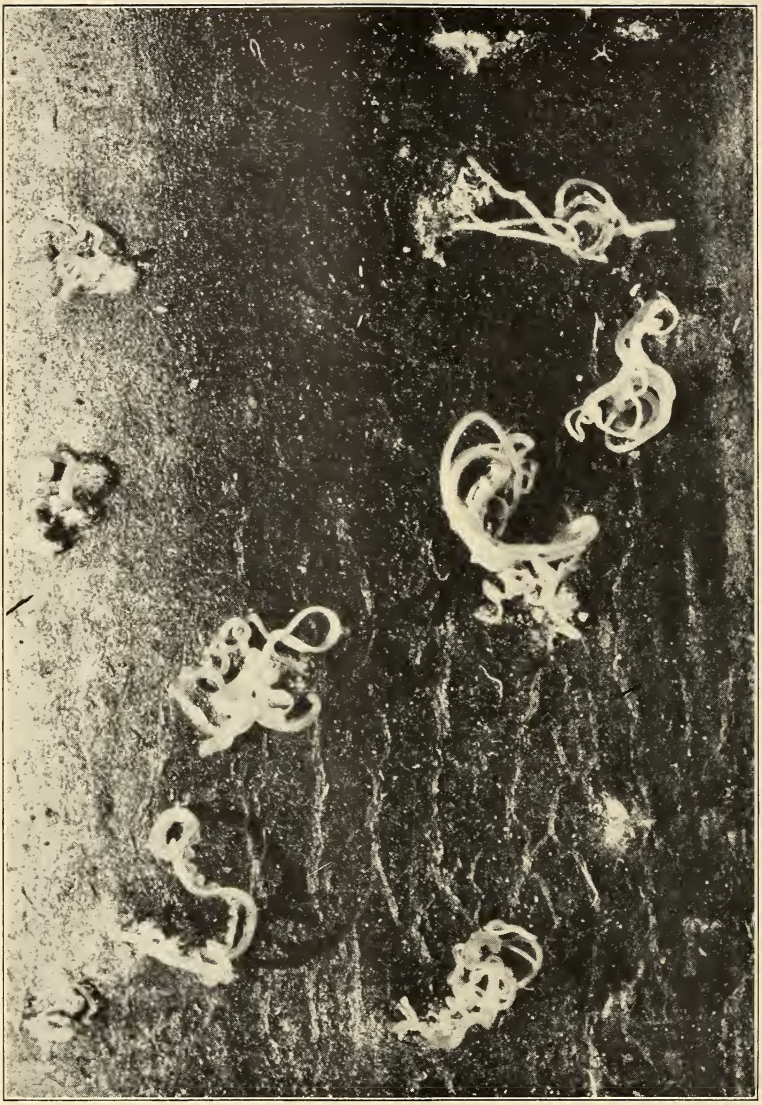
FANS OF WHITE OR BUFF-COLORED MYCELIUM OF CHESTNUT BLIGHT

These fans are exposed by peeling back the outer bark of the tree and constitute the most reliable evidence of the presence of the blight fungus



BLIGHT PUSTULES ON CHESTNUT

A, Chestnut-blight canker showing the fruiting pustules of the causal fungus, which in dry weather often resemble orange or red-brown pinheads. B, Necks of the flasklike structures may be seen protruding from some of the blight pustules



HAIRLIKE SPORE HORNS WHICH COIL OUT FROM CERTAIN OF THE BLIGHT PUSTULES DURING DAMP WEATHER

(12 times natural size)

The infection spreads rapidly. In general, from two to six trees will be found blighted for every one which had the disease the preceding season. Since the severity of attack as well as the number of trees infected increases, the presence of the parasite rapidly becomes evident.

When approximately 80 per cent of the chestnut is attacked, the killing effect of the fungus is shown by the presence of scattered dead and half-dead trunks as well as numerous dead limbs and branches. At this stage of the disease the lumberman and the farmer are usually aware of the need of prompt cutting. The class in which 80 per cent or more of the trees is infected has been selected as desirable for use in forecasting the spread of the disease. (Pl. VI.)

There are two methods of predicting the time a given area will become 80 per cent blighted. By one method the percentage of infection in a locality is multiplied by an annual factor, giving the period which may be predicted as required for that stand to become 80 per cent blighted. The second method consists in plotting the extension of the 80 per cent zone at the same rate it is known to have advanced in the past. In extending to the southwest across the State of Virginia this rate was approximately 24 miles a year. Its extension to the west across the valleys and ridges was less rapid. In forecasting the future spread by this method allowance must be made for any outstanding spot infections, for they, too, will throw out waves of the disease. In making the forecasts for the accompanying map (fig. 2), the two large spot infections, one in the Saluda Mountains and the other in northern Georgia, were allowed for.

These methods have been combined in preparing the forecast map. (Fig. 2.) Like the 1924 distribution map, from which it was prepared, the forecast map is not to be thought of as dealing with individual wood lots. It treats of the area as a whole. Nor is its accuracy, even as a whole, to be considered assured. It is based upon limited surveys and dependent on average conditions. The possible existence of large spot infections in counties not yet examined or only partially covered is a source of probable error. At present it is believed that by 1930 well over half the counties of the southern Appalachians will be 80 per cent blighted and that by 1935 nine-tenths of them will have passed that stage. New forecasts will be made when the available information from future surveys indicates that changes are needed. Owners of chestnut timber should make plans in advance to secure proper utilization before deterioration causes heavy losses.

DETERIORATION

A tree trunk girdled by the blight dies, just as girdled branches die; and, as with the branches, the larger the trunk to be girdled the longer the fungus requires to kill the part. In general a large part of the chestnut in a blighted stand will die within from two to five years following the reaching of the 80 per cent infection stage. A few trees, however, will be blight-killed when the tract is 80 per cent infected, and others will not be dead six years after that stage is reached.

The effect of girdling by blight is similar to that produced when a tree is ringed with an axe. The tree is killed, but its value for timber is not lessened. Tests made by the Forest Products Laboratory show that the chestnut blight alone does not impair the strength or durability of the wood. Like the ringed tree, however, blight-killed chestnut is subject to deterioration when not promptly used. This deterioration is brought about by secondary causes. Wood-decaying fungi promptly establish themselves in the areas of bark and sapwood which have been killed, sometimes even before the tree itself is completely dead. Within two years, and oftentimes even sooner, areas of sap rot are present. Insects burrowing under the bark and through the sapwood spread the rot-producing organisms and loosen the bark. In from four to five years following the death of the tree most of the bark and part of the rotted sapwood slough off, leaving the trunk bare (Pl. VII). While the sap rot is at work other deterioration takes place. The timber becomes dry and brittle. It is harder to cut, and breakage in felling is more frequent. Checking begins in from two to five years after the tree dies, small trees checking more rapidly than large ones. Excessive checking greatly reduces the value of the timber for purposes other than fuel or extract wood. Many timber worms gain entrance through blight cankers and at other places when the tree is dying, thus reducing the grade of lumber from such trees.

Where a considerable part of the stand is chestnut, fire conditions become increasingly critical with the accumulation of bark, dead sprouts, and fallen branches at the bases of dead trees. Fires not only often destroy part of the dead standing chestnut but also, on account of the intensity with which the accumulated dead material burns, frequently destroy other tree species in the stand. Adequate fire protection in the southern Appalachians would materially assist in the effort to utilize the chestnut growth and would materially prolong the life of the chestnut-extract industry.

SALVAGE AND UTILIZATION

North of the Mason and Dixon line from 10 to 40 per cent of the value of the standing chestnut was lost through deterioration which followed blight. In the South, where the stand contains a larger proportion of chestnut, heavier loss threatens unless the rate of cutting is immediately increased. Eventual destruction of all commercial chestnut by the blight is inevitable. Consequently each owner of chestnut is forced to decide for himself what part of his timber can be salvaged at a profit. He must weigh the value of the material, the difficulty of getting it out and ready for market, its transportation to the point of sale, and the labor and equipment available for performing the task within a limited time.

The problem of quickly utilizing the chestnut timber from the 33,000,000 acres of the southern Appalachians, where the species represents 25 per cent of the stand, is one phase of the chestnut-blight problem which the Forest Service and State and extension forestry departments are endeavoring to solve.

This country already feels the early stages of the increasing scarcity of timber. A large part of our lumber supply is hauled

thousands of miles to market. Yet in the southern Appalachians, fairly close to the large consuming markets, we face the prospect of the loss through deterioration, before it can be used, of vast quantities of chestnut suitable for sawed products. The wholesale price of chestnut lumber, at least of the lower grades, is hardly sufficient to pay the cost of marketing. The situation emphasizes the need of employing chestnut on a national scale for purposes where it is practicable to substitute it for that of species not in need of immediate cutting.

Chestnut lends itself to the most varied usage of any timber species growing in the southern Appalachians. It is already used for extract wood, lumber, poles, ties, mine props, piles, fence posts, cordwood, and pulpwood, and it offers the possibility of increased employment.

Sawed chestnut lumber is much in demand, but because of the blight the market tends to be glutted. The wood is light and easily worked. It can be used for many purposes where its coarse grain and lack of extreme strength do not make it undesirable. Its increased use for sheathing, framing, interior work, and most of all for the manufacture of boxes, packing cases, and crates would do much to conserve other timber supplies.

Telephone and telegraph poles command the highest prices paid for chestnut. From the standpoint of utilization it is particularly fortunate that poles can be marketed at less cost than any chestnut product of equal value. Pole cutting is not dependent on any other lumbering operation, and no expensive equipment is necessary. The likelihood of flooding the pole market is serious, though the number of chestnut trees suited to the purpose is limited. Pole specifications of length, straightness, moderate diameter, and freedom from knots, rots, and injuries are so exacting as to exclude much material. Except on tracts where sprouts from the stumps of cut-over stands are of pole size, few poles are produced per acre. In short, poles represent the chestnut product selling for the highest price and at the same time are easily removed. Timber owners would do well to follow the practice of the Forest Service in the national forests in the southern Appalachians, where all chestnut suitable for poles is cut as a first measure of utilization.

The manufacture of chestnut extract affords the most feasible outlet for much of the stand. Extract plants are already established strategically over the southern Appalachian district. This industry, by far the largest consumer of chestnut, uses enormous quantities of the wood. It disposes of trees and parts of trees that are worthless except as acid wood. The limbs as well as trunks are used, so that little waste remains in the woods to increase the fire hazard. Best of all, from the standpoint of the present situation, even the prolonged standing of dead timber does not exclude its use for this purpose.

While it simplifies utilization, the tannin-extract industry at the same time presents one of the most important problems arising from the present situation. The American chestnut supplies approximately one-half of this country's production of tannin for leather manufacture. With this species facing extermination, to what future source of raw material must this vital industry look?

What other valuable species can be used to reforest the land once occupied by the chestnuts? This is an important silvicultural problem. The best means of bringing about the replacement of the chestnut with other valuable species of trees is being studied by the Appalachian Forest Experiment Station at Asheville, N. C., in cooperation with various States. State and extension foresters are rendering assistance to private owners in planning for the utilization of their chestnut stands.

BLIGHT-RESISTANT CHESTNUTS

Since direct control of chestnut blight is impracticable, the discovery of suitable strains of chestnut resistant to the disease is highly desirable. Individual native chestnuts show differences in susceptibility to attack, but the number of trees actually surviving in regions where blight has been present longest is very small. Search for many years has disclosed only a few native specimens. Some of these trees are being propagated and further studied with the hope of developing a strain of American chestnut sufficiently resistant to attain maturity in the presence of the disease. It has been found that the numerous living trees which occur on tracts recently blight-killed are generally disease-escaping rather than disease-resistant; for this reason search for resistant specimens is profitable only on areas where all but very exceptional chestnut trees have been dead from the disease for a number of years. Reports of such resistant trees are desired. The Office of Forest Pathology records all such trees reported and inspects them as field work permits.

A number of Japanese and Chinese species and strains of chestnut have been brought to this country in the hope of obtaining a tree which will thrive despite the chestnut blight. None of the trees so far imported and tested have proved immune, but the Japanese chestnut (*Castanea japonica*) and the hairy Chinese chestnut (*C. mollissima*) have considerable natural resistance. A number of these trees are known to have survived the blight, and reports of others are desired. Strains of these oriental chestnuts show marked differences in susceptibility, and it is impracticable to control the blight on some of the very susceptible ones. However, most of the oriental trees can be saved by systematically cutting out any cankers which may appear and painting the wounds. Detailed information will be supplied by the Office of Forest Pathology to anyone interested in treating such trees.

Most of the imported chestnuts so far tested have been suited for orchard culture rather than timber production. Other strains and additional species of Asiatic chestnut are being introduced by the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry. There is reason to expect that ultimately among these introductions, resistant native strains, or crosses among these various forms, a tree will be found which possesses sufficient resistance to grow to timber size in the presence of the disease.

SUMMARY

The chestnut blight is caused by a fungus introduced into this country on nursery stock from Asia. The organism attacks the bark of the chestnut and forms cankers. These ultimately girdle and kill the parts affected, the dead foliage remaining persistent.

A county by county survey begun in 1924 and still in progress has discovered infections at the southern limit of commercial chestnut. Westward the spread of the disease has been less rapid than southward. It is believed that by 1930 more than half, and by 1935 nine-tenths, of the counties in the southern Appalachians will have reached the stage at which more than 80 per cent of their trees will be infected.

No practical control is known, but if salvaged before deterioration sets in the lumber from blight-killed trees is equal to that cut from live trees. Great need exists for increased cutting and use of chestnut, so that this timber may be utilized and other species conserved.

Search is being made for native and foreign chestnuts resistant to the disease in the hope of finding a tree suitable for partially replacing our rapidly disappearing stands.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

March 15, 1926

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